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Issued October 28, 1911.

U. S. DEPARTMENT OF AGRICULTURE,
FOREST SERVICE—BULLETIN 103.
HENRY S. GRAVES, Forester.

DISTINGUISHING CHARACTERISTICS OF NORTH AMERICAN GUMWOODS,

BASED ON THE ANATOMY OF THE SECONDARY WOOD.

BY

GEORGE B. SUDWORTH, Dendrologist,

AND

CLAYTON D. MELL, Assistant Dendrologist.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Forest Service,
Washington, D. C., August 9, 1911.

Sir: I have the honor to transmit herewith a manuscript entitled "Distinguishing Characteristics of North American Gumwoods," by George B. Sudworth, dendrologist, and Clayton D. Mell, assistant dendrologist, and to recommend its publication as Bulletin 103 of the Forest Service.

Respectfully,

Henry S. Graves,
Forester.

Hon. James Wilson,
Secretary of Agriculture.

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DISTINGUISHING CHARACTERISTICS OF NORTH AMERICAN GUMWOODS.

OUR NATIVE GUMS.

The North American trees commonly known as "gums"[1] belong chiefly to the genus *Nyssa*, to which the well-known dogwoods (*Cornus*) are closely related, and to the genus *Liquidambar*, which is of a wholly unrelated family (Hamamelidaceæ). Only the gums belonging to *Nyssa* are dealt with in this bulletin. Of these there are altogether five species, four of which are natives of the eastern United States, occurring within the territory from southern Ontario to Florida and westward to Texas. The fifth species (*Nyssa sessilifolia*) is a native of southern Asia and adjacent islands. Our native species are the black gum (*Nyssa sylvatica*), water gum (*Nyssa biflora*), sour tupelo (*Nyssa ogeche*), and cotton gum (*Nyssa aquatica*).

The last three gums generally grow in moist or wet soils, while the black gum usually grows on high ground. All except *N. ogeche* yield woods that are now being used extensively for commercial purposes. The wood has remarkably twisted fibers, which render it very difficult to split, and some gums are much used for heavy wheel hubs, rollers, and farm implements. Gumwoods are used also for a great many other purposes, including flooring, siding, piano tops, turned columns, packing cases, crates, boxes, baskets, pump logs, and for crossties. The wood of water gum and cotton gum are suitable and used to a considerable extent now for grills, coffins, sounding boards of musical instruments, slack-cooperage stock, turned table legs, spindles, balusters, for various construction material, and for paper pulp, the fibers of the wood being as long as those of basswood and the color good enough for print paper. The demand for these woods will doubtless continue to increase and, later, they will probably replace, to a certain extent, a great many other woods now used for the above purposes.

---

[1] The probable origin of the common name "gum" as applied to these trees is, in case of the *Nyssas*, from the early use in the South of sections of hollow trunks for beehives, which were called "bee-gums," later being shortened to "gum" as a name for the tree itself. In the case of Liquidambar, of which we have but one native species, commonly called "sweet gum" and "red gum," the earliest name, sweet gum, doubtless originated from the domestic use for chewing of the sweetish gum obtained from the tree. The later name, red gum, refers to the reddish-brown color of the wood.

Our native species of *Nyssa* can readily be distinguished in the forest by their leaves, fruit, and bark characters, but the woods of these trees as they reach the market are much less easily identified, because they have no striking superficial characteristics. Moreover, wood from different trees of the same species varies greatly in color, weight, hardness, and odor, and for this reason it is necessary to depend for critical identification chiefly upon the structural characters of the different species.

The analytical key prepared for the identification of the different species is based upon the gross and minute anatomy of the secondary[1] wood of the mature stem. In addition to the key, descriptions are given of the different woods and their elements, together with the geographical range of each species, and other useful information, including a list of the common or trade names.

The analytical key is designed as an aid chiefly to technically trained students, who will derive much aid also from a careful study of macerated[2] material, in which the elements of the wood are completely separated. In this condition accurate measurements can be made of the elements and the constant differences in the dimensions of those of each species serving accurately to distinguish the species. The general descriptions and illustrations of the different gumwoods will, it is believed, enable most laymen to satisfactorily identify each species. It is important to note that accurate information as to where a sample of gumwood was collected often facilitates the identification. Thus *Nyssa* wood collected in Pennsylvania could at once be identified as black gum (*Nyssa sylvatica*), because this is the only species growing in that State.

GROSS STRUCTURE OF GUMWOODS.[3]

SAPWOOD AND HEARTWOOD.

The heartwood of the *Nyssas* is not always easily distinguishable from the sapwood, which is usually quite thick in all species excepting *Nyssa ogeche*. The depth of color, which is usually the most obvious character of heartwood, is dependent upon the age of the tree and to a great extent also upon the nature of the soil in which the tree is growing: but primarily it depends upon the structure of the wood itself. The heartwood of *Nyssa sylvatica* usually varies from light yellow to very light brown, which may indicate that, to a certain extent, one tree may have taken from the soil very little highly colored substance, which in its upward course in the stem has been deposited on the inner walls of the wood elements in the form of gum and resin derivatives, while an example of darker heartwood would indicate that the trees have taken up a larger amount of coloring matter.

---

[1] Sapwood and heartwood, the strictly woody parts of a tree stem, are collectively known as secondary wood, a technical name given to mature wood because its formation follows in the order of development the growth of tissue known as primary wood, which is intermediate in character between the purely parenchymatous tissue of pith and fully matured wood. The general order of growth in a tree stem is, therefore, first, the production of the purely parenchymatous tissue of pith; second, the formation of primary wood; and, third, the laying on of secondary wood. Following the production of pith and primary wood comes the formation of the so-called "cambium ring," a generative layer of thin-walled cells, which develops secondary wood on its inner side and bark on its outer side.

[2] The wood of this genus can readily be macerated by Schultze's method, which consists in putting small pieces of wood into a test tube and pouring on just enough dilute nitric acid to cover them. A few crystals of potassium chlorate are then added and the test tube gently heated until bubbles appear and the specimens turn white. After the material has been thoroughly washed and placed in a vial containing water, the fibers can be separated by thorough shaking.

[3] For a discussion of the general structure of woody stems see Bulletin 102, The Identification of Important North American Oak Woods.

ANNUAL RINGS OF GROWTH.

Annual rings of growth can not be clearly distinguished with the unaided eye, and often can be scarcely distinguished by means of a magnifying glass. In all species of *Nyssa* the outlines of such layers of growth are clearly shown in a transverse microscopic section by from 2 to 4 rows of wood fibers (fig. 6, *w. f.*), the radial diameters of which are greatly reduced toward the periphery of the layer of growth (fig. 6, *a. r.*), whereas the fibers first formed during the succeeding growing period are of the usual size. Occasionally the radial diameters of the small vessels (fig. 6, *v.*) near the periphery of the layer of growth are somewhat diminished and their number is slightly decreased. It has been observed in a number of annual rings of growth that the vessels are more numerous and that their diameters are somewhat greater near the middle of the layer than elsewhere; also that the number of wood fibers per unit area slightly increases toward the periphery.

The annual rings of growth are usually very narrow in most samples of *Nyssa* wood obtained from that part of the tree trunk above the enlarged base. The normal annual diameter increase is approximately between 2 and 4 millimeters.[1] The enlarged base of a tree shows the diameter increase to be frequently from two to three times as fast as at other points in the trunk, while the structure there is generally less dense and the wood very light and soft compared to that farther up the stem.

All elements of these gumwoods are uniformly distributed throughout the annual rings of growth. The vessels are occasionally arranged in short radial rows or groups, but they are small and nearly equal in size. In a general way this structure is similar to that of the woods of maples, magnolias, red gum, and cottonwoods, which also have diffuse porous structure.

The annual rings of growth as seen in transverse sections do not exhibit a sharply defined limitation of the early and late wood.

---

[1] A millimeter is about one twenty-fifth of an inch.

(Fig. 6, *a. r.*) Ordinarily in cone-bearing trees and also in the majority of broad-leafed trees the late wood, which corresponds to that portion of the annual rings generally referred to as summer wood, constitutes the bulk of the layer. In the *Nyssas*, however, it is impossible to determine where the early wood ends and the late wood begins.

MINUTE STRUCTURE OF THE WOOD.

VESSELS.

These elements as seen in a transverse section are mostly round or irregularly polygonal. (Fig. 6, *v.*) When four or more occur in a group, they are generally triangular in outline. The cross walls are strongly oblique, with their slanting sides always facing the pith rays and invariably perforated by transversely elongated pits arranged in parallel rows, known as scalariform (ladder-like) perforations. (Fig. 1, *sc. p.*) The upper and lower ends of these oblique cross walls often show slight reticulations, though invariably the thickenings in cross walls bear close resemblance to the rungs and spaces of a ladder, and of which there are generally from 20 to 40 or more in a single cross wall. A few instances have been noted where the number of these bars exceed 75. In the related exotic genera, *Davidia* and *Ausuba*, the number of perforations is still greater, while in the related native genus *Garrya* they seldom exceed 5.

The walls of the vessels are much thinner than those of the wood fibers, which are discussed further on. Numerous measurements of vessel segments show marked variations within the same species, which may be attributed to the different internal and external conditions of growth, such as soil and the influence of situation and exposure. The actual thickness of the vessel walls is approximately the same for all species. The measurements given in Table 1 show the relative width of the vessels separated by macerating.

TABLE 1.—*Average, maximum, and minimum diameter of vessel segments of the four species.*

Species.	Average.	Maximum.	Minimum.
	Mm.	*Mm.*	*Mm.*
Nyssa sylvatica	0.101	0.132	0.076
Nyssa ogeche	.099	.127	.071
Nyssa aquatica	.075	.095	.063
Nyssa biflora	.062	.079	.056

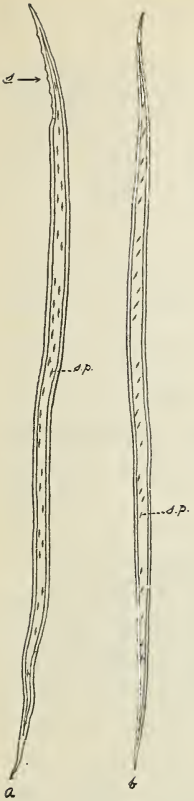

Fig. 2.

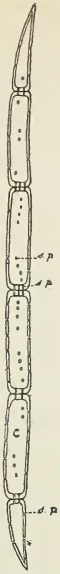

Fig. 3

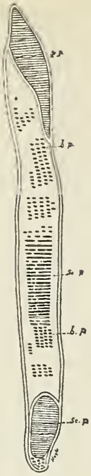

Fig 1

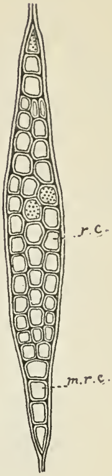

Fig. 4.

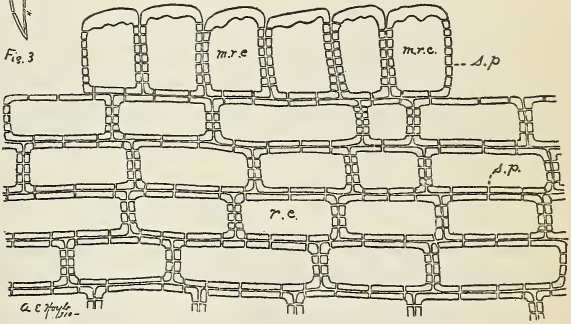

Fig. 5.

FIG. 1.—Vessel segment (tracheæ) of cotton gum (*Nyssa aquatica*) showing scalariform (ladder-like) perforations (*sc. p.*) at both ends; also elongated pit-like marking on the radial walls. Bordered pits (*b. p.*) arranged in regular rows. Magnified about 100 diameters.

FIG. 2.—Wood fibers showing simple pits (*s. p.*). *a.* Wood fibers of cotton gum (*Nyssa aquatica*) showing elongated openings of simple pits (*s. p.*) parallel with the axis of the fiber and serratures (*e.*). *b.* Wood fiber of *Nyssa sylvatica* showing elongated openings of simple pits (*s. p.*) oblique to the axis of the fiber. Magnified about 55 diameters.

FIG. 3.—Wood-parenchyma fiber of cotton gum (*Nyssa aquatica*) showing individual cells (*c.*) and the arrangement of the simple pits (*s. p.*). Magnified about 100 diameters.

FIG. 4.—Transverse section of a pith ray of cotton gum (*Nyssa ogeche*) showing the regular ray cells (*r. c.*) and the marginal ray cells (*m. r. c.*). Magnified about 50 diameters.

FIG. 5.—Part of pith ray of cotton gum (*Nyssa aquatica*) showing the individual ray cells (*r. c.*) and marginal ray cells (*m. r. c.*) with simple pits (*s. p.*). Magnified about 200 diameters.

The length of vessel segments varies considerably. The measurements given in Table 2 show the varieties in this dimension.

TABLE 2.—*Average, maximum, and minimum lengths of vessel segments of the four species.*

Species.	Average.	Maximum.	Minimum.
	Mm.	*Mm.*	*Mm.*
Nyssa biflora	1.102	1.457	0.728
Nyssa aquatica	1.059	1.401	.756
Nyssa ogeche	1.050	1.218	.756
Nyssa sylvatica	1.012	1.218	.756

The walls of vessels are densely marked by bordered pits (fig. 1, *b. p.*) arranged in many rows, which are plainly visible under the high power of a microscope both in tangential and in radial sections. The pits on vessels adjacent to other vessels, to tracheids,[1] and to wood fibers having bordered pits are bordered on both sides of the common wall; but where the vessels are contiguous to parenchyma cells or to wood fibers having simple pits, the pits in the vessel walls are bordered, and in the wall of the parenchyma cell or wood fiber they are simple. The pits on vessel walls are small and very numerous where they lie next to pith-ray cells. In rare instances the cavities of pits arranged in horizontal rows on the radial walls of vessels run into each other and form one continuous unthickened portion, which gives the appearance of scalariform markings. (Fig. 1, *sc. p.*) This, however, has been observed only in the wood of *Nyssa aquatica.*

WOOD FIBERS.

These elements are sometimes round or from four to eight sided, with long and rather thin ends, which frequently have more or less serrated edges on their radial walls. (Fig. 2 *a, s.*) These serratures, seen only in macerated material, are impressions caused by the adjoining pith rays, which lie at right angles to the fibers. The length of the fibers varies considerably, though the difference in the average lengths for the four species, as shown in Table 3, is slight compared with the variations exhibited in wood fibers of the same species.

---

[1] In *Nyssa,* wood-prosenchyma fibers, which include all elements having their long axes parallel with the stem, have very thin walls, except in *N. sylvatica,* and relatively wide lumina (cell cavities). Both wood fibers and tracheids have bordered pits, and it is sometimes difficult to distinguish these two kinds of elements. They are so nearly alike that it is thought best not to discuss them separately, but to include them with the wood fibers. In cases where tracheids have been distinguished from the wood fibers they were invariably found immediately bordering vessels. Ordinarily they can be very easily distinguished from the wood fibers by their relatively wide lumina and by their blunt ends.

TABLE 3.—*Average, maximum, and minimum lengths of fibers of the four species.*

Species.	Average.	Maximum.	Minimum.
	Mm.	*Mm.*	*Mm.*
Nyssa aquatica	1.717	2.325	1.176
Nyssa sylvatica	1.679	2.374	1.071
Nyssa ogeche	1.574	2.101	1.092
Nyssa biflora	1.560	2.157	1.055

The walls of the wood fibers are generally thin, except in the wood of very slow-growing trees and in wood taken from the crown of the tree or from a point some distance above the buttress. In fast-growing trees the walls are very thin, especially in the wood taken from near the base of the tree. The pits, which can be seen best in a radial section or in macerated material, are either simple (fig. 2*a*, *s. p.*), having slit-like openings about half as long as the width of the fibers, or occasionally a few fibers may have round bordered pits. The slit-like openings are either oblique or parallel with the axis of the fiber and usually they are arranged in a single row (fig. 2 *a* and *b*).

WOOD-PARENCHYMA FIBERS.

Wood-parenchyma fibers occur sparingly in the wood of *Nyssas.* They may be recognized in transverse sections by their thin walls and by the presence of crystals of calcium oxalate in the cells. They are scattered regularly through the wood and are usually adjacent to vessels, but seldom occur isolated among groups of thick-walled elements. Radial or tangential bands of wood parenchyma, so common in the oaks and hickories, are entirely wanting in this group of woods. These fibers can be seen best in tangential sections as perpendicular rows of short cells arranged end to end (fig. 3, *c.*), and which usually border pith rays or vessels. The end cells invariably taper to blunt ends. The cross walls between the individual cells are usually horizontal, and are always marked by small, round, simple pits (fig. 3, *s. p.*). In radial sections the pits are numerous and occur in small groups or rows, but in tangential sections they occur rather sparingly. Wood-parenchyma fibers bordering vessels are usually much flattened and have numerous pits, but where they occur among wood fibers they are prismatic and contain very few pits. It frequently happens that they are adjacent to pith rays on one side and to vessels on the other. In such cases they are marked by numerous pits on both sides.

The individual cells of wood-parenchyma fibers contain substance similar to that of the pith-ray cells, and in addition to this also crystals of calcium oxalate and calcium carbonate. The latter are easily soluble in hydrofluoric acid and do not appear in the microscopic sections prepared in the ordinary way.

Crystals of calcium oxalate, frequently quite conspicuous under the microscope, are wholly confined to the cells of the wood-parenchyma fibers. These are best observed in a tangential section where they are solitary or more frequently in longitudinal series of a few to 20 or more crystals. The cubical cells of the wood-parenchyma fibers containing these tetragonal or pentagonal crystals are technically known as idioblasts, which are modified, thin-walled wood-parenchyma cells. Their cavities are invariably completely filled with the crystalline mass.

PITH-RAY CELLS.

The pith rays (fig. 6, *p. r.*) in the wood of the four species of *Nyssa* possess marked taxonomic value. The tangential section shows pith rays that are from one to four rows wide, though the majority of them are only one row wide. They vary considerably in height even within the same species. Such variations are not sufficiently constant, however, to serve as specific distinctions. Variations in width are more constant. *Nyssa aquatica* has pith rays that seldom have more than two rows of cells, while those of other Nyssas frequently have from three to four rows of cells. All pith rays with many rows of cells, as seen in a tangential section, taper abruptly above and below to an acute point (fig. 4). The cells which terminate the pith rays (tangential section) are known as marginal ray cells (figs. 4 and 5, *m. r. c.*), and are narrow, considerably elongated in the direction of the wood fibers. The cells in the middle of the pith ray are square or round (fig. 4, *r. c.*). These cells in radial section (fig. 5, *r. c.*) are from two to four times as long as wide, while those near the upper and lower edge of the pith ray are cubical. All the pith-ray cells contain numerous simple pits (fig. 5, *s. p.*) where they border vessels and other parenchymatous tissue. The pits communicating between the pith-ray cells and vessels are simple in the walls of the former and bordered in the latter.

The pith rays, as seen in transverse sections (figs. 6, 7, 8, and 9), are invariably wider at the points where they intersect the boundaries of annual rings of growth. The ray cells at and near the periphery of the annual rings are also notably shorter in a radial direction than they are elsewhere.

CHARACTERS USED FOR IDENTIFICATION.

GROSS CHARACTERS.

The wood of all species is light, soft, tough, cross-grained, and difficult to split. The lightness of the wood is dependent upon its diffuse porous structure, as is also the softness of its tissue, which in *Nyssa aquatica* and *Nyssa ogeche* is easily indented under the thumb nail.

The following specific gravity determinations of air-dried material were made at the Forest Products Laboratory, Madison, Wis.:

Species.	Specific gravity.	Weight per cubic foot.
		Pounds.
Nyssa ogeche	0.527	32.93
Nyssa aquatica	.542	33.88
Nyssa biflora	.500	31.20
Nyssa sylvatica	.635	39.59

The wood of the root of all species is appreciably lighter in weight and is easily distinguished from the wood of the stem by the very thin walls and comparatively wide cavities of the cells. It is used largely in the preparation of tupelo-sounds. The vessels and the wood fibers in the roots have nearly equal diameters, which have been determined to be 0.105 millimeter.

MINUTE CHARACTERS.

Transverse section.—Diffuse porous, i. e., having numerous pores distributed more or less regularly throughout the annual rings which begin with a single, tangential, and greatly interrupted row of pores, but in the later development of the growth rings the pores are either arranged singly or in short radial rows of 2 to 4 each; they occur less frequently in small groups. These characters can be seen with a strong pocket lens.

Radial section.—Bordered pits of the vessel walls arranged in 3 to 6 rows. Pith-ray cells are of two kinds; the cells in the middle of the ray are from 2 to 4 times as long as wide, and the marginal cells are from 1 to 3 times as wide as long, while they are generally less than one-half as long radially as the other ray cells. These characters can be seen adequately only under a compound microscope.

Tangential section.—Pith rays rather numerous, in rows of from 1 to 5 and from a few to 40 cells high, the upper and lower rows of cells being much larger than those in the center. These characters can be seen adequately only under a compound microscope.

Macerated material.—In this condition the elements in the wood are all separated and can be studied to advantage in so far as their markings are concerned, and also with respect to their general shape and size. Measurements of the elements can be made only with the aid of a compound microscope and a micrometer eyepiece.

ANALYTICAL KEY FOR IDENTIFYING GUM WOODS.

Pith rays composed of from 1 to 2 rows of cells, rarely of 3 to 4 rows.
  Vessels numerous and grouped slightly radially.
    Elongated simple pits on the radial walls of the wood fibers parallel to the cell lumina ---------------------------- 1. *Nyssa aquatica* (p. 14.)

Pith rays composed of from 1 to 5 rows of cells, usually of 3 to 4 rows.
  Vessels very numerous and evenly distributed.
    Elongated simple pits on the radial walls of wood fibers parallel or nearly so with the cells lumina___________ 2. *Nyssa biflora* (p. 16.)
  Vessels less numerous and evenly distributed.
    Elongated simple pits on the radial walls of wood fibers oblique.
      Vessels small and usually solitary.
        Walls of wood fibers thick and lumina small.
          3. *Nyssa sylvatica* (p. 17.)
      Vessels large and usually in groups of 2 to 4.
        Walls of wood fibers thin and lumina large.
          4. *Nyssa ogeche* (p. 19.)

CHARACTERISTICS OF THE DIFFERENT GUMS.

Cotton Gum. *Nyssa aquatica* Linn. (fig. 6).

Common names in use.—Large tupelo (Ala., La., Tex.); Tupelo gum (Ga., Ala., Miss., La.); Sour gum (Ark., Mo.); Swamp tupelo (So. Ga., La.); Cotton gum (N. C., S. C., Fla.); Tupelo (N. C., S. C.); Swamp gum (N. C.); Bowl gum (N. C.); Ladle gum (N. C.); Papaw gum (N. C.); White gum (N. C.); Wild olivetree (La.); Oliver a grandes feuilles (La.); Olivetree (Miss.).

Distribution.—Coast region from southern Virginia to northern Florida and through the Gulf States to Texas (Nueces River); northward through Arkansas, west to Tennessee and Kentucky, southern and southeastern Missouri to southern Illinois (lower Wabash River).

Gross characters.—The wood is soft, light, not strong, though tough, close-grained, and splits rather easily compared with the wood of *N. biflora.* The heartwood is nearly white or sometimes cream colored or even light brown in old trees; the sapwood is somewhat lighter and usually quite thick. The annual rings of growth are not clearly defined on a transverse section and there is no noticeable distinction between early and late wood within the layer. The outer boundary of a growth ring is marked by a few rows of radially flattened wood fibers which can be seen with the aid of a compound microscope.

Minute characters.—*Vessels* (fig. 6, *v.*) in a transverse section are regularly distributed throughout the annual rings of growth. Each succeeding layer begins with a greatly interrupted row of pores immediately bordering the flattened wood fibers of the next preceding rings. Numerous pores are distributed singly or in short radial rows of 2 to 4 each. Occasionally small circular groups of pores occur here and there, in which case the individual ones are usually quite irregular in outline. They are usually most abundant in the middle of a layer, and gradually diminish in number toward the inner and outer boundaries. The vessels vary in diameter from 0.076 to 0.132 millimeter, with an average of 0.099 millimeter (see Table 1). The vessel segments vary in length from 0.756 to 1.218 millimeters and have an average length of 1.059 millimeters (see Table 2). In outline they are round, polygonal or occasionally somewhat flattened near the outer edge of the layer. The vessel walls are quite thin and contain numerous small, round, bordered pits arranged in numerous rows. The cross walls are oblique and are perforated with numerous much elongated pits known as scalariform markings, or crossbars, which vary in number from 20 to 60. *Wood fibers* (fig. 6, *w. f.*) vary from 1.176 to 2.325 millimeters in length and have an average length of 1.717 millimeters (see Table 3). They are longer than those of any other native species of this genus. The cell walls are thick and contain from 1 to 2 rows of elongated simple pits which are almost invariably parallel with the long axes of wood fibers. The slit-like openings in the cell walls are often much longer than the cell is wide. When they are oblique they always point in a left-hand direction around the fiber. *Wood-parenchyma fibers*[1] are almost invariably contiguous with vessels and pith rays and communicate with them through small, round, simple pits. Where they border other wood-parenchyma or pith-ray cells the pits are always simple on both sides of the middle lamella, but where they are in contact with vessels

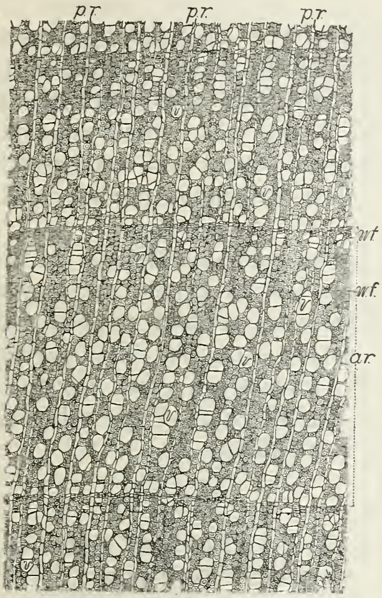

Fig. 6.

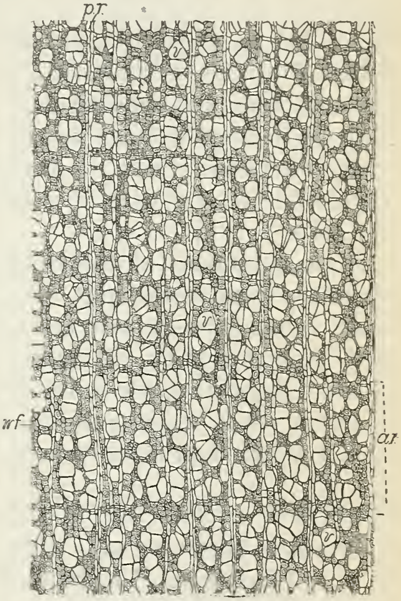

Fig. 7.

FIG. 6.—Transverse section of the wood of cotton gum (*Nyssa aquatica*) showing two entire annual rings of growth (*a. r.*); *v.*, vessels; *w. f.*, wood fibers; *p. r.*, pith rays. Magnified 20 diameters.

FIG. 7.—Transverse section of the wood of water gum (*Nyssa biflora*) showing 6 entire annual rings of growth. Magnified 20 diameters.

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[1] These elements can not be distinguished from wood fibers except with the aid of a compound microscope.

the pits are simple in the walls of the former and bordered in the walls of the latter. This is true for all woods in which these elements are contiguous. The walls are, as a rule, rather thin and contain numerous simple pits on the radial side. Numerous crystals of calcium oxalate are present here and there in long vertical rows of from a few to 24 or more crystals. *Pith rays* (fig. 6, *p. r.*) consist of radially directed parenchyma cells from 1 to 2 rows wide and from a few to many cells high. The individual cells vary considerably in length and width; those near the middle of the ray are from two to four times as long as wide with somewhat rounded ends. They resemble four to eight-sided prisms giving a mural effect in radial section. The marginal cells are considerably larger than the regular ray cells. They are shorter radially than the cells in the middle of the ray, but they are considerably wider. Pith-ray cells communicate with each other through small, round, simple pits, which are especially numerous where the ray cells border vessels and wood-parenchyma fibers. Crystals of calcium oxalate are seldom present in the ray cells.

Some specimens of the wood of cotton gum are difficult to distinguish from water gum (*N. biflora*), but as a rule cotton-gum wood is less cross-grained and consequently less difficult to split than that of water gum. Moreover, the cotton gum has very narrow annual rings of growth in which the vessels are often arranged radially, while water gum has wider annual rings of growth with vessels distributed more or less evenly throughout.

Water gum. *Nyssa biflora* Walt. (fig. 7).

Common names in use.—Gum (Va., N. C.); Lowland gum (Va., N. C.); Black gum (Va., N. C., S. C.); Lowland black gum (N. C.); Swamp black gum (N. C.).

Distribution.—Maryland (Montgomery County) to Florida and central Alabama. The bulk of the lumber coming on the market as Tupelo is of this species.

Gross characters.—The wood is moderately soft and heavy, not strong, though exceedingly tough, even grained, and splits with great difficulty. The heartwood is light brown or sometimes cream colored; the sapwood is thick and almost pure white. The annual rings of growth are not clearly defined, nor is there any distinction between early and late wood.

Minute characters.—*Vessels* (fig. 7, *v.*) in transverse section are more or less numerous, and are generally distributed singly or in small circular groups of two to five pores each; less often in short radial rows. They are rather irregular in outline, frequently flattened radially, particularly those near the outer boundary of the annual rings of growth. The walls are usually very thin, and are marked by numerous small bordered pits, which are arranged in numerous rows where they touch parenchyma cells or other vessels. The cross walls are oblique and perforated by very numerous scalariform markings. The average diameter of the vessels is 0.101 millimeter and their average length is 1.059 millimeters, or approximately 10 times as long as wide (see Tables 1 and 2). *Wood fibers* (fig. 7, *w. f.*) vary from 1.055 to 2.157 millimeters in length, with an average length of 1.560 millimeters (see Table 3). In length they are next to *N. aquatica*, and exhibit very little if any difference in diameter or thickness of the cell wall. The pits are simple and slit-like openings in the cell walls. These openings are parallel, or nearly so, with the axis of the fiber. *Wood-parenchyma fibers* occur very sparingly in the wood of Nyssas. They stand in close connection with vessels and pith rays, with which they communicate through small round pits. Their walls are very thin and contain numerous pits where they border pith-ray cells or vessels. The pits are particularly abundant on the cross walls. Crystals of calcium oxalate are distributed here and there in rather long vertical rows. *Pith rays* (fig. 7, *p. r.*) are arranged in from one to five rows and from a few to many cells high. The cells near the middle of the ray as seen in a radial section are from two to four times as long as wide, while those near the upper and lower edge are frequently squarish. The cross walls are usually perpendicular or slightly oblique, with rounded edges. The marginal cells of the pith rays are usually much larger, especially in the direction of the axis of the tree, but are as a rule much shorter radially than those near the middle of the ray. Pith-ray cells contain numerous small, round, simple pits where they touch other wood-parenchyma fibers or vessels. Crystals of calcium oxalate are entirely wanting in pith-ray cells.

(See description under cotton gum (*N. aquatica*) for possible confusion of this with the wood of water gum.)

Black Gum. *Nyssa sylvatica* Marsh (fig. 8).

Common names in use.—Black gum (N. J., Pa., Del., Va., W. Va., N. C., S. C., Ga., Ala., Miss., La., Tex., Ill., Ind.); Sour gum (Vt., Mass., R. I., N. Y., N. J., Pa., Del., Va., W. Va., S. C., Fla., Tex., Ohio, Ind., Ill.); Tupelo (Mass., R. I., N. J., Del., Va., W. Va., S. C., Fla., Miss., Tex., Ill., Ohio); Pepperidge (Vt., Mass., R. I., N. Y., N. J., S. C., Tenn., Mich., Ohio, Ont.); Wild peartree (Tenn.); Yellow gumtree (Tenn.); Gum (Md., Pa., N. J.); Stinkwood (W. Va.); Tupelo gum (Fla.).

Distribution.—From Maine (Kennebec River) to Florida (Kissimmee River and Tampa Bay) and west to southern Ontario, southern Michigan (up to Gratiot County), southeastern Missouri and Texas (Brazos River).

Gross characters.—The wood is rather hard, heavy, strong, exceedingly tough, close-grained, and splits only with great difficulty. The heartwood is cream colored or sometimes very light brown; the sapwood is much lighter colored and usually quite thick. The annual rings of growth vary considerably in width, and there is little distinction between the early and late wood. The wood is so tough that it can be successfully used for the hubs of wheels, rollers in glass factories, ox yokes, and sometimes for the soles of shoes. Owing to its large proportion of sap the wood is not durable in contact with the soil, though it is occasionally used for wharf piles.

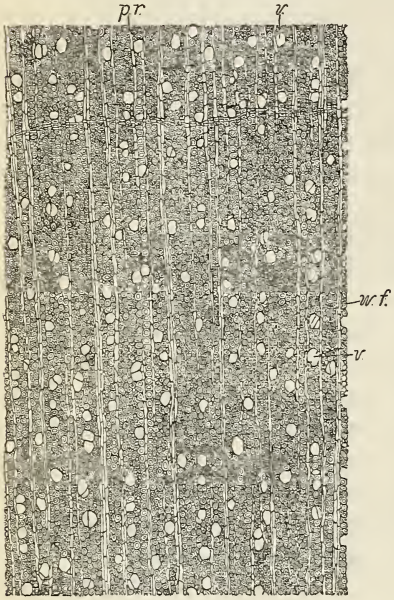

Fig. 8.

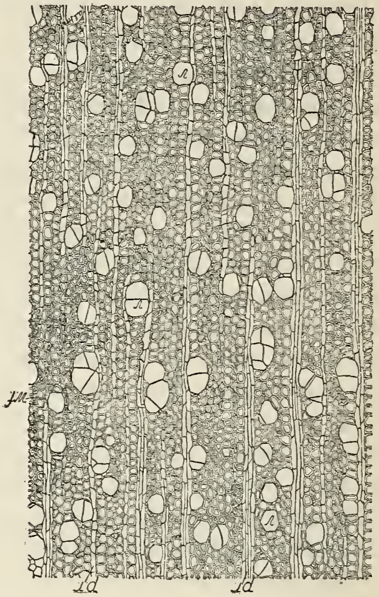

Fig. 9.

Fig. 8.—Transverse section of the wood of black gum (*Nyssa sylvatica*) showing parts of two annual rings of growth. Magnified 20 diameters.

Fig. 9.—Transverse section of the wood of sour tupelo (gum) (*Nyssa ogeche*) showing a portion of an annual ring of growth. Magnified 20 diameters.

Minute characters.—*Vessels* (fig. 8, *v.*) in the transverse section are evenly distributed throughout the annual rings of growth. Those immediately bordering the radially flattened wood fibers of the next preceding layer form a much interrupted tangential line. They are usually scattered singly, though they often occur in small groups and vary in diameter from 0.063 to 0.095 millimeter, with an average diameter of 0.075 millimeter (see Table 1). The average length of vessel segments is 1.012 millimeters and vary from 0.756 to 1.218 millimeters (see Table 2). In outline they are round, polygonal or frequently flattened either radially or tangentially. The walls of the vessels are thin and are marked by numerous rows of bordered pits. The cross walls are strongly oblique and are perforated by numerous elongated horizontal pits. Wood fibers (fig. 8, *w. f.*) vary from 1.071 to 2.374 millimeters in length with an average length of 1.679 millimeters (see Table 3). The cell walls are thick and are marked by one or occasionally two rows of much elongated simple pits on the radial walls. These pits are almost invariably oblique and are longer than the width of the wood fibers and always point in a left-hand direction around the cell. *Wood-parenchyma fibers* are invariably contiguous to vessels and to pith rays, with which they communicate through small, round, and simple pits. The walls are exceedingly thin and contain numerous pits where they border vessels and pith-ray cells. The cells composing this tissue are generally from one to four times as long as wide and are conspicuous in longitudinal sections. Crystals or calcium oxalate are abundant here and there in vertical rows from a few to 24 or more. *Pith rays* (fig. 8, *p. r.*) are from 1 to 2 rows wide and from a few to many cells high. The individual cells vary considerably in length and width; those near the middle of the ray are from two to four times as long as wide with slightly rounded ends. The marginal cells are considerably larger than the regular pith-ray cells. They are shorter radially than the cells in the middle of the ray, but they are much longer in the direction of the axis of the stem. The pits are very numerous where they border vessels and other parenchyma cells. Crystals of calcium oxalate are wanting in pith-ray cells.

Black gum usually resembles the wood of water gum (*N. biflora*), but from which it is readily distinguished by its less numerous and less conspicuous pores. Black gum is also considerably heavier and more difficult to split than the wood of water gum.

Sour Tupelo. *Nyssa ogeche* Marsh (fig. 9).

Common names in use.—Sour Tupelo (S. C., Fla.); Ogeche lime (S. C., Fla.); Gopher plum (Fla.); Tupelo; Wild limetree; Limetree (S. C.).

Distribution.—From southern borders of South Carolina (near coast and through the Ogeeche River Valley in Georgia) to northern Florida (Clay County) and western Florida (Santa Rosa County).

Gross characters.—The wood is soft, light, tough, and splits with less difficulty than the wood of any of the other species. The heartwood is very light colored, occasionally rather light brown but hardly distinguishable from the exceedingly thin and almost pure white sapwood. The annual rings of growth are not clearly defined in a transverse section and there is no distinction between early and late wood. This species is rare and local and is seldom cut for lumber except occasional trees, and then the wood is marketed as cotton gum. The tree rarely attains 80 feet in height and 2 feet in diameter.

Minute characters.—Vessels (fig. 9, *v.*) are evenly distributed through the annual rings of growth. They usually occur singly, though frequently in small groups of from two to three arranged in radial rows. They vary from 0.056 to 0.079 millimeter in diameter and have an average diameter of 0.062 millimeter. The average length of the vessel segments is 1.05 millimeters. They vary in length from 0.756 to 1.218 millimeters (see Tables 1 and 2). The walls of vessels are very thin and are marked by numerous rows of bordered pits. The cross walls are oblique and are perforated by numerous elongated horizontal pits. *Wood fibers* (fig. 9, *w. f.*) vary from 1.092 to 2.101 millimeters and have an average length of 1.574 millimeters (see Table 3). The walls are thin and are marked by one or occasionally two rows of much elongated simple pits on their radial sides. These slit-like openings are invariably oblique and occasionally longer than the total width of the fiber. They always point in a left-hand direction around the fiber. *Wood-parenchyma fibers* generally border vessels and pith rays, with which they communicate through small, round, simple pits. The walls are very thin and are marked by numerous pits on the cross walls. The cells composing the wood-parenchyma fibers are generally from one to four times as long as wide and are conspicuous in a longitudinal section. Crystals of calcium oxalate are abundant in some samples of this wood. They occur in vertical rows from a few to 24 or more. *Pith rays* (fig. 9, *p. r.*) are from one to five rows, generally from three to four rows wide and from a few to many cells high. The individual cells vary considerably in length and width; those near the middle of the ray are from two to four times as long as wide and have slightly rounded ends. The marginal cells are considerably larger than the regular ray cells. They are shorter radially than the cells in the middle of the ray, but they are much wider in the direction of the axis of the stem. The pits are very numerous where they border vessels and other parenchyma cells. Crystals of calcium oxalate are wanting in the pith-ray cells.

The wood of sour tupelo is very light, soft, and has larger and more numerous pores than the wood of the other gums.